OLLSCOIL NA GAILLIMHE
UNIVERSITY OF GALWAY

# ***Semester 1 Examinations 2022-2023***

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| **Course Instance Code(s)** | 4BCT, 4BS, 4BMS |
| **Exam(s)** | B.Sc. (CS&IT)<br>B.Sc.<br>B.Sc. (Biomedical Sc.) |
| **Module Code(s)** | CT404, CT336 |
| **Module(s)** | Graphics and Image Processing |
| Paper No. | 1 |

| | |
|---|---|
| External Examiner(s) | Dr. R. Trestian |
| Internal Examiner(s) | Prof. M. Madden<br>*Dr. S. Redfern |

**Instructions:**

- Answer **three questions**
- Of which **at least one must be Graphics** (Q1, Q2, Q3)
- And **at least one must be Image Processing** (Q4, Q5)
- Your third question can come from either (Q1, Q2, Q3, Q4, Q5)
- All questions carry equal marks.

| | |
|---|---|
| **Duration** | 2 hours |
| **No. of Pages** | 7 |
| **Discipline(s)** | Computer Science |
| **Course Co-ordinator(s)** | Dr. C. O'Riordan |

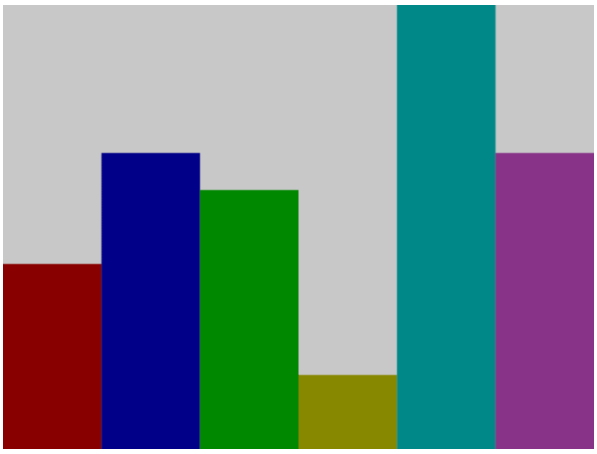
**Requirements:**

| | | |
|---|---|---|
| Release in Exam Venue | Yes [ x ] | No [ ] |
| MCQ Answersheet | Yes [ ] | No [ x ] |
| Handout | None | |
| Statistical/ Log Tables | None | |
| Cambridge Tables | None | |
| Graph Paper | None | |
| Log Graph Paper | None | |
| Graphic material in colour | Yes [ x ] No [ ] | |

**Q.1. (Graphics)**

(i) Provide short sections of code illustrating **translation**, **rotation**, and **scaling** in either Canvas2D or Threejs. *Note that the final page of this exam paper lists some commonly used functions in Canvas2D and Threejs.* [8]

(ii) Using the code below as a starting point, write Javascript/Canvas2D code for use in the **draw()** function which will draw a bar chart from the data contained in the **data[]** array. Note that each entry in the **data[]** array is an object containing both a value and a colour. The chart should apply appropriate scales on the *x* and *y* axes, bearing in mind that the number of entries in **data[]** as well as their values may change, i.e. you should not hard-code the scales. There is no requirement to label the axes. [12]



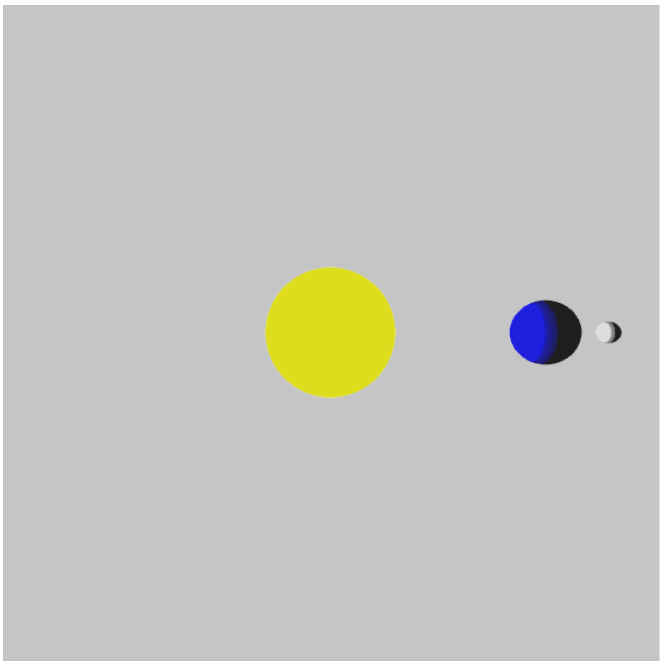
```
<html>
  <head>
    <script>
    function draw() {
        var canvas = document.getElementById("canvas");
        var ctx = canvas.getContext("2d");
        var data = [
          {val:5, color:"#880000"}, {val:8, color:"#000088"},
          {val:7, color:"#008800"}, {val:2, color:"#888800"},
          {val:12, color:"#008888"}, {val:8, color:"#883388"},
        ];
        // to do: write code here to draw a bar chart using Canvas2D


    }
    </script>
  </head>

<body onload='draw();'>
  <canvas id="canvas" width="600" height="450"></canvas>
</body>
</html>
```

**Q.2. (Graphics)**

Examine the **Javascript/Threejs** code provided below (and on the next page), which sets up a display of a sun, planet, and moon as in the picture below.



(i) In order for the program to provide an animation whereby the blue planet rotates around the yellow sun, while at the same time the grey moon rotates around the blue planet, it will be necessary to **nest their coordinate systems using pivots**. Explain what this means and why it is necessary. [7]

(ii) Provide the code changes that are needed in the **draw( )** function to establish this nesting. *Note that the final page of this exam paper lists some commonly used functions in Threejs.* [7]

(iii) Write suitable code for the **animate( )** function to apply a small amount of rotation per frame, to the planet pivot so that the planet orbits the sun, and to the moon pivot so that the moon orbits the planet. [6]

```
<html>
 <head>

  <script src="three.js"></script>
  <script>
    'use strict'

    var renderer, scene, camera;
    var sun, planet, moon;

    function draw() {
      // create renderer attached to HTML Canvas object
      var c = document.getElementById("canvas");
      renderer = new THREE.WebGLRenderer({ canvas: c, antialias: true });
```

```
      // create the scenegraph
      scene = new THREE.Scene();
      scene.background = new THREE.Color( 0x333333 );

      // create a camera
      var fov = 75;
      var aspect = 600/600;
      var near = 0.1;
      var far = 1000;
      camera = new THREE.PerspectiveCamera( fov, aspect, near, far );
      camera.position.set(0, 0, 20);
      camera.lookAt(new THREE.Vector3(0,0,0));

      // add a light to the scene (at the location of the sun)
      var light = new THREE.PointLight(0xFFFFFF);
      light.position.set(0, 0, 0);
      scene.add(light);

      // create the sun, planet, and moon
      sun = new THREE.Mesh(
        new THREE.SphereBufferGeometry(3,60,60),
        new THREE.MeshBasicMaterial({color: 0xffff00}) );
      sun.position.set(0, 0, 0);
      scene.add(sun);

      planet = new THREE.Mesh(
        new THREE.SphereBufferGeometry(1.5,60,60),
        new THREE.MeshLambertMaterial({color: 0x0000AA}) );
      planet.position.set(10, 0, 0);
      scene.add(planet);

      moon = new THREE.Mesh(
        new THREE.SphereBufferGeometry(0.5,60,60),
        new THREE.MeshLambertMaterial({color: 0x888888}) );
      moon.position.set(13, 0, 0);
      scene.add(moon);

      animate();
    }

    function animate() {
      setTimeout(animate, 20);

      renderer.render(scene, camera);
    }
  </script>
 </head>

 <body onload="draw();">
   <canvas id="canvas" width="600" height="600"></canvas>
 </body>
</html>
```

**Q.3. (Graphics)**

(i) Many of the techniques used in real-time 3D graphics programming attempt to maximise the realism of the rendered scene while processing a minimal number of polygons. With specific reference to the so-called 'polygon budget', and using diagrams where appropriate, discuss each of the following techniques: [12]

a) Frustum Culling
b) Back Face Culling
c) Portal Culling
d) Levels-of-Detail (LODs)

(ii) Real time graphics algorithms are categorised as operating in either **world space** or in **image space**. Explain the meaning of world space algorithms and image space algorithms from the point of view of the rendering pipeline. List one algorithm which could operate in world space (and explain why world space is appropriate to it) and list one algorithm which could operate in image space (and explain why image space is appropriate to it). [8]

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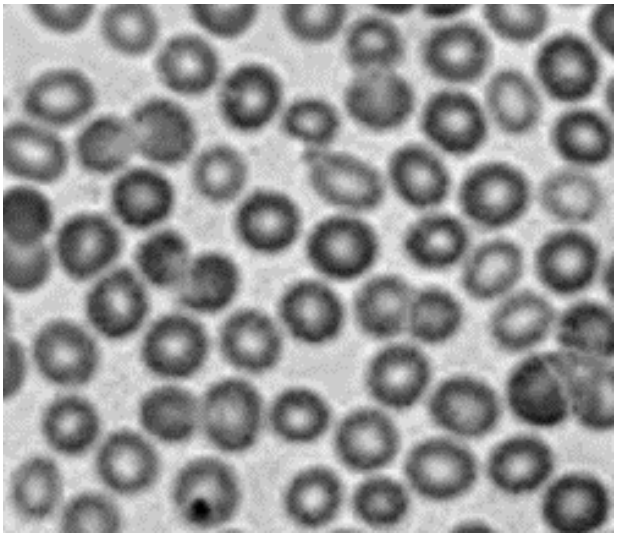
**Q.4. (Image Processing)**

(i) With respect to morphological image processing, outline the following operations: **erosion**, **dilation**, **opening**, and **closing**, as applied to binary images. What are these operations useful for? [10]

(ii) The image below is of blood cells, and it is required that a fully automated system is developed to accurately count the number of cells in images such as this. Present a suitable and robust set of image processing algorithms for this task. Explain why each step you have chosen is appropriate. [10]



**Q.5. (Image Processing)**

(i) Many automatic image analysis algorithms begin by **smoothing** an image, and then applying an **edge detection** filter in order to ascertain the evidence for the edges of objects in the image.

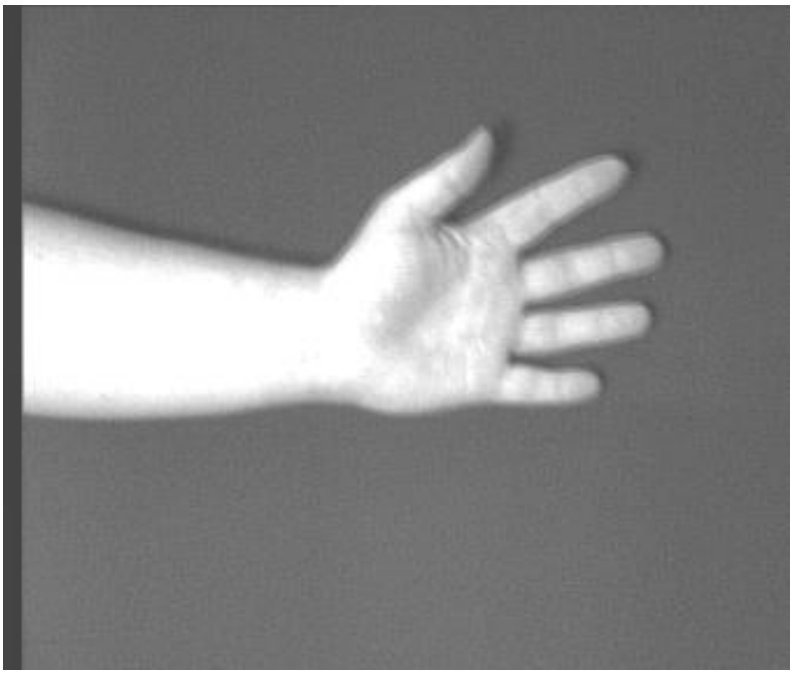
a) Discuss the use of smoothing and edge detection for these purposes. [5]

b) Discuss two approaches that might be used to deal with problems such as fragmentary edges and occluded edges. [5]

(ii)

a) Discuss the image processing technique called **active contours**. In your answer, explain in simple terms the algorithmic concept of **optimisation**. [5]

b) Describe a suitable set of optimisation constraints (sometimes called energy factors) for accurately tracing the outline of a hand in an image such as the one shown below, using active contours. What purpose does each constraint have? [5]



## Some useful methods/properties of the Canvas 2D Context object:

| Method/Property | Arguments/Values | Notes |
|---|---|---|
| fillRect | (Left, Top, Width, Height) | Draw a filled rectangle |
| beginPath | None | Start a stroked path |
| moveTo | (X, Y) | Move the graphics cursor |
| lineTo | (X, Y) | Draw a line from graphics cursor |
| stroke | None | End a stroked path |
| fillStyle | ="rgb(R,G,B)" | Set fill colour |
| strokeStyle | ="rgb(R,G,B)" | Set line colour |
| save | None | Save the current coordinate system |
| restore | None | Restore the last saved coord system |
| translate | (X,Y) | Translate the coordinate system |
| rotate | (angle) | Rotate the coordinate system clockwise, with angle in radians |
| scale | (X,Y) | Scale the coordinate system independently on the X and Y axes |

## Some useful objects/methods from the Threejs library:

| Object/Method | Notes |
|---|---|
| new THREE.WebGLRenderer({canvas:c}) | Constructs a renderer, attached to the Canvas object c |
| new THREE.PerspectiveCamera(fov,aspect,near,far) | Constructs a camera, with the specified field-of-view, aspect ratio, near clipping distance, far clipping distance |
| new THREE.Scene(); | Constructs a scene |
| new THREE.PointLight(0xffffff); | Constructs a white point light |
| object.position.set(x,y,z) | Sets an object's x,y,z position relative to its parent |
| object.rotation.set(x,y,z) | Sets an object's x,y,z rotation (using Euler angles) relative to its parent |
| object.rotateOnAxis(new THREE.Vector3(0,1,0), 0.1) | Rotates object by 0.1 radians on the y axis |
| object1.add(object2) | Sets object2 as a child of object1 |
| object.parent | Obtains a reference to the parent of object |
| camera.lookAt(new THREE.Vector3(0,0,0)); | Turns a camera object to face the world coordinate 0,0,0 |
| new THREE.BoxGeometry(20, 20, 20) | Constructs Box geometry, with specified width, height, depth |
| new THREE.MeshLambertMaterial({color: 0xfd59d7}) | Constructs a Lambert (Phong) material of the specified colour |
| new THREE.Mesh(geometry, material) | Constructs a mesh using the specified geometry and material |
| renderer.render(scene, camera) | Uses a renderer to draw a scene as seen by a camera, onto the renderer's Canvas |